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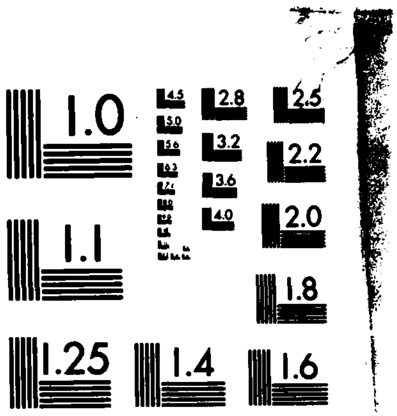

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TECHNICAL REPORT 149

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JULY 1983

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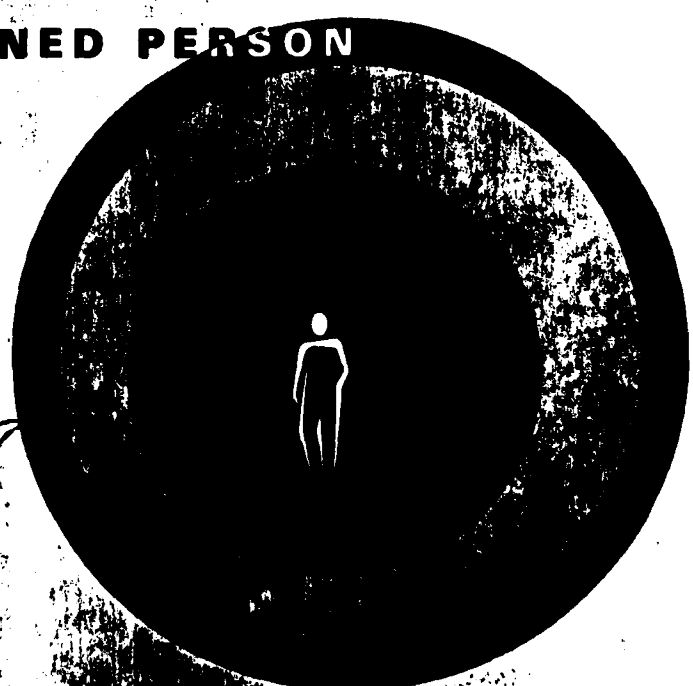

TRAINING ANALYSIS AND EVALUATION GROUP
ORLANDO FLORIDA 32813

Technical Report 149

KNOWLEDGE RETENTION AMONG GRADUATES OF BASIC ELECTRICITY AND ELECTRONICS SCHOOLS

Eugene R. Hall
Larry H. Ford
Timothy C. Whitten

Training Analysis and Evaluation Group

and

LCDR L. R. Pylant

Chief of Naval Technical Training

July 1983

ALFRED F. SMODE, Ph.D., Director
Training Analysis and Evaluation Group

W. L. MALOY, Ed.D.
Principal Civilian Advisor on Education and Training

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> This study assessed the extent of knowledge decay during the interval between graduation from Basic Electricity and Electronics (BE/E) School and entry into a Construction Electrician (CE) "A" School. The results indicated that BE/E knowledge does decay and that the amount of decay is related to student ability characteristics. Decay had no apparent affect on subsequent "A" School achievement.

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SECTION I

INTRODUCTION

The Chief of Naval Technical Training (CNTECHTRA) Training Program Coordinator (TPC) for the Construction Electrician (CE) "A" School observed that remedial training in basic electricity and electronics (BE/E) information was desirable for students entering CE "A" School. One possible explanation for this need was that knowledge previously acquired at Navy BE/E Schools had not been well retained between the period following BE/E graduation and CE "A" School entry. Thus, the TPC (CNTECHTRA, Code N422), to assess this possibility, requested that the CE "A" Schools retest entering students. The Training Analysis and Evaluation Group (TAEG), with the concurrence of the Chief of Naval Education and Training (CNET), assisted CNTECHTRA by analyzing and interpreting the available data.

PURPOSE

The principal purpose of the CNTECHTRA/TAEG effort was to assess the extent of knowledge decay during the interval between graduation from BE/E School and entry into a CE "A" School. Additional purposes of the study were to determine if knowledge decay

- is related to the retention interval (i.e., time between schools)
- is influenced by student ability characteristics
- is affected by the BE/E School attended
- is affected by retest procedures at the CE "A" Schools entered
- impacts on student CE "A" School achievement.

In addition to examining the basic issue of BE/E knowledge decay, the TPC was also interested in determining if changes to the currently used selection criteria could improve student survivability within the CE training pipeline. Thus, an ancillary purpose of the study was to examine the probable results of alterations to current selection criteria.

PERSPECTIVE ON RETENTION

The issue of retention of learned technical skills and knowledges has long been of concern to the Navy. The extent to which acquired capabilities are forgotten over periods of nonuse has implications for many Navy programs and policies. In pipeline training programs, for example, knowledge losses over even relatively short periods of time may diminish the potential effectiveness of succeeding courses in the pipeline and/or require unprogrammed and unbudgeted remedial training. Personnel utilization policies and practices must also contend with the retention problem. What happens to acquired capabilities when a seasoned individual is assigned a tour as a recruiter or when a new technical school graduate is assigned nonjob related duties for some period of time? Similar questions are of concern to those charged with structuring and manning the reserve forces. Are some critical

skills and knowledges more susceptible to decay than others? What steps should be taken to assure the availability of these capabilites in times of need?

Current information about skill and knowledge decay is sketchy and incomplete. What is known stems largely from a small number of longitudinal studies which have provided limited empirical data about the retention of specific acquired capabilities. Although many retention phenomena could be predicted from the results of psychological learning experiments, the legitimacy of such generalizations to skills and knowledges essential for manning the Navy is unknown. In all, retention has been a relatively neglected area of investigation, and much information is needed to propose solutions to existing problems. The basic information needed concerns the retention problem itself; that is, the:

- extent to which learned skills and knowledges may deteriorate or decay over periods of nonuse

- types of skills and knowledges most/least susceptible to decay

- rate(s) at which decay occurs.

Information on these basic issues is prerequisite to the development of procedures, policies and practices for maintaining skills and knowledges at acceptable levels and to the specification of relearning requirements for forgotten capabilities.

Definitive answers to the many questions about skills retention would require a long term programmatic effort. This type of effort, however, is prohibitive since it involves extensive costs for personnel testing and retesting and deliberate nonuse of personnel in trained-for specialties for varying periods of time. The present study is noteworthy for the opportunity it provides to develop an initial understanding of the problem of deterioration and to formulate realistic, practical approaches to contending with the problem over time.

The present study provides important information that has been previously unavailable about the extent to which learned technical information is forgotten during periods of nonuse. The results obtained have direct implications for management of the CE training pipeline. They also have implications for other pipelines involving initial BE/E training. From a much broader perspective, this study is important to the Navy at large for the opportunity provided for an initial assessment of the nature of the problem of retention of acquired capabilities.

ORGANIZATION OF THE REPORT

The remainder of this report is presented in four sections and two appendices. Section II presents the technical approach of the study. The study results are given in section III and discussed in section IV. Conclusions and recommendations are provided in section V. A copy of the instructions provided the CE "A" School by CNTECHTRA for testing BE/E knowledge is contained in appendix A. Appendix B presents the results of a particular statistical analysis performed for the study.

SECTION II

TECHNICAL APPROACH

This section presents the technical approach to the study. The background to the study is presented first. Subsequently, discussions are provided of the basic study data, the variables examined and data analysis procedures employed.

STUDY BACKGROUND

Within the CE training pipeline, prospective CEs, immediately after completion of recruit training, attend a BE/E School at one of three Naval Training Centers: Orlando, FL; San Diego, CA; or Great Lakes, IL. Graduation from BE/E School requires successful completion of both phases (parts) of a standardized comprehensive final examination. Phase 1 covers DC theory; phase 2, AC theory. Following BE/E School, prospective CEs are ordered to a CE "A" School at either Port Hueneme, CA or Gulfport, MS. Suspecting that knowledge acquired at BE/E School may have decayed in the interval between BE/E graduation and entry into a CE "A" School, the responsible CNTECHTRA TPC (Code N422) requested that the CE "A" School staffs retest entering students. Subsequently, 307 BE/E graduates (covering the period between January and November 1981) were retested. Prior to the retest, students were given a 2-hour classroom period in which they could use BE/E study guides to refresh themselves on material covered in BE/E. An instructor was present to answer questions. No group lectures were provided. The following morning, students were given a multiple choice examination identical to the final examination taken at BE/E School. Students were encouraged to guess if they were not sure of the correct answer. The CNTECHTRA instructions for accomplishing the retesting are contained in appendix A.

STUDY DATA

All test data, and other data needed to address the study objectives, were provided TAEG by the CE "A" School TPC. The data included:

- identifying information on each student
- BE/E School attended
- location of the retest site (i.e., CE "A" School entered)
- final BE/E test, phase 1 scores (number correct out of a maximum score of 47)
- retest phase 1 scores
- final BE/E test, phase 2 scores (number correct out of a maximum score of 29)
- retest phase 2 scores

- scores of CE "A" School students on selected subtests of the Armed Services Vocational Aptitude Battery (ASVAB)
- BE/E graduation date
- BE/E retest date
- CE "A" School final grades (these grades were available only for graduates of the CE "A" School in Gulfport).

In addition to the above data, the TPC provided TAEG with ASVAB subtest scores on students selected to attend CE "A" School but who had attrited from BE/E School. This information was used for separate analyses concerned with possible improvement of criteria currently used to select individuals for CE "A" School training.

STUDY VARIABLES

The data provided by CNTECHTRA were used to compose variables for assessment. These variables, described below, are presented in the approximate order of their occurrence in a CE "A" School student's history. The variables examined include student ability characteristics, the BE/E School attended, final BE/E test score grades, knowledge retention interval, the CE "A" School entered, BE/E retest score and CE "A" School grades.

ABILITY CHARACTERISTICS. Relationships among measures of student ability, student achievement, and knowledge loss were examined. The ability measures used were AFQT percentile scores and ASVAB selector composite scores.

AFQT Percentile Scores. Armed Forces Qualification Test (AFQT) percentile scores were used as measures of general ability. AFQT percentile scores, derived from three subtests of the ASVAB, are used in selecting recruits for entrance into the service.

ASVAB Composite Scores. Composite scores made up from various combinations of ASVAB subtest scores are used by the Navy to select individuals for attendance at specific technical schools. Routine selection for CE "A" training requires that a student's score on the Arithmetic Reasoning (AR) subtest plus twice his score on the Mechanical Knowledge (MK) subtest plus his score on the General Science (GS) subtest (i.e., AR + 2MK+ GS) equal or exceed 200. Analyses were conducted to (1) assess the relationships among composite scores and knowledge decay and (2) examine the effects of using different composites and different cut-off scores for CE "A" School selection.

BE/E SCHOOL ATTENDED. As mentioned previously, BE/E training is conducted at Naval Training Centers in San Diego, Orlando, and Great Lakes. Location of the final BE/E test site (i.e., school attended) was used as a variable to determine its relationship to knowledge decay. Of specific concern was the equivalency of final test scores across the three sites.

FINAL BE/E TEST SCORE. Student total final test scores and scores on each phase of the BE/E final examination were used as separate criterion variables. The phase scores were used to determine if the predictor variables (e.g., ability levels, school attended) were differentially related to the specific knowledge measured by each test phase (i.e., DC theory for phase 1, AC theory for phase 2).

RETENTION INTERVAL. The retention interval is the number of days between a student's final examination at BE/E School and his retest at CE "A" School. During this time, students could have been in transit or awaiting instruction.

CE "A" SCHOOL ENTERED. After BE/E, students entered CE "A" School at either Port Hueneme or Gulfport. CE "A" School entered was used as a variable to determine if, for example, different retest practices at each school might affect an apparent knowledge decay.

RETEST SCORE. The BE/E retest examination was identical to the final BE/E examination. The difference between the final BE/E test score and the retest score divided by the final test score reflected the proportion of knowledge lost over time for any given graduate.

CE "A" SCHOOL GRADES. End-of-course grades were available only for those graduates who attended CE "A" School in Gulfport. These final grades, derived from objective and subjective measures, represent an average of test scores and a student's demonstrated performance in class. These school grades were used as a criterion variable to determine if any knowledge decay observed adversely affected achievement in CE "A" School.

MISCELLANEOUS VARIABLES. In addition to the study variables discussed above, difference scores were also computed for each phase of the BE/E test and retest. The difference scores were computed by subtracting the final BE/E test scores from the retest scores. Therefore, a positive difference score indicates a BE/E graduate's retest score was higher than his final BE/E test score, while a negative difference score indicates a BE/E graduate's retest score was lower than his final BE/E test score.

DATA ANALYSIS

Analyses conducted were designed to address the following specific questions:

1. Is there evidence of knowledge decay? If so, what is its relationship to:

   - retention interval
   - student ability characteristics
   - BE/E and CE "A" School sites
   - CE "A" School final grades?

2. What is a desirable ASVAB composite/cut-off score for selecting individuals for the CE pipeline?

Regression analyses, analyses of variance and t-tests were used for standard data analyses. Discriminant function analysis was used to develop an alternative ASVAB composite. Trade-off curves were developed for both the currently used ASVAB composite and an alternative composite.

SECTION III

RESULTS

This section presents the results of the study. Presented first is a description of the total study sample. Second, descriptive information about BE/E graduates who went on to CE "A" School is provided. Next, the evidence for BE/E knowledge decay is given, and, finally, the relationships between CE "A" School grades, ability and knowledge decay are presented.

STUDY SAMPLE

A total of 381 BE/E students in the CE "A" pipeline were in the sample. Of these, 307 graduated from BE/E and went on to attend CE "A" School; 54 attrited from BE/E for academic reasons and 20 attrited for nonacademic reasons. The entire sample, by BE/E School attended, is shown in table 1. Various analyses performed are based on smaller samples either because they concern only BE/E graduates or because of missing data.

TABLE 1. SAMPLE OF BE/E STUDENTS

	Attrited		CE "A" School	
BE/E School	Academic	Nonacademic	Gulfport	Port Hueneme
Orlando	21	9	99	41
San Diego	23	7	14	53
Great Lakes	10	4	50	32
Unidentified	0	0	8	10
TOTALS	54	20	171	136

DESCRIPTIVE INFORMATION ON CE "A" SCHOOL STUDENTS

This subsection presents descriptive information on BE/E graduates who went on to attend CE "A" School. The mean AFQT percentile and ASVAB composite scores, BE/E test scores, and retention intervals are presented.

AFQT AND ASVAB SCORES. The mean AFQT and ASVAB scores for BE/E graduates by BE/E and CE "A" School attended are shown in tables 2 and 3. There are no significant differences among any of the schools in AFQT scores or ASVAB composite scores. Thus, each BE/E School and each CE "A" School receives students of equivalent ability levels.

TABLE 2. AFQT PERCENTILE SCORES

BE/E School	CE "A" School	Mean	S.D.*	Number
Great Lakes		59.68	13.30	81
	Port Hueneme	57.56	13.09	32
	Gulfport	61.06	13.38	49
San Diego		61.92	18.18	66
	Port Hueneme	61.39	18.74	52
	Gulfport	63.93	16.43	14
Orlando		59.26	17.08	127
	Port Hueneme	59.30	16.60	37
	Gulfport	59.24	17.36	90

*S.D. = standard deviation
NOTE: Two-way Analysis of Variance showed no significant differences among BE/E Schools or CE "A" Schools.

TABLE 3. ASVAB COMPOSITE SCORES

BE/E School	CE "A" School	Mean	S.D.*	Number
Great Lakes		219.55	13.18	82
	Port Hueneme	218.23	12.31	32
	Gulfport	220.40	13.77	50
San Diego		221.55	16.48	65
	Port Hueneme	221.32	17.19	53
	Gulfport	222.58	13.47	12
Orlando		219.14	16.14	117
	Port Hueneme	216.13	14.43	40
	Gulfport	220.70	16.84	77

*S.D. = standard deviation
NOTE: Two-way Analysis of Variance showed no significant differences.

BE/E TEST SCORES. Average final BE/E test scores are shown in table 4. There are no significant differences among final test scores by BE/E School, nor are there any differences between scores of students who went to either CE "A" School. Thus, the measured knowledge level of graduates of the three BE/E Schools is equivalent as is the knowledge level of graduates going to each CE "A" School site.

Average BE/E retest scores are also shown in table 4. There are no significant differences in overall average retest scores between students at the two CE "A" Schools. This finding indicates that retest scores were not unduly influenced by retest practices at either school. However, there are significant differences in retest scores depending on which BE/E School was attended. Specifically, students who attended BE/E School in San Diego and CE "A" in Port Hueneme scored significantly higher on both phases of the retest than students from Orlando or Great Lakes who also attended CE "A" School at Port Hueneme. However, there were no significant differences among students from the different BE/E Schools who attended CE "A" School at Gulfport.

RETENTION INTERVAL. The average retention intervals in days for the different BE/E - CE "A" School pipelines are shown in table 5. When averaged over all students, there are no significant differences between the two CE "A" Schools in retention interval. However, there are significant differences in retention interval depending on the BE/E School attended. Specifically, students going from Orlando to Port Hueneme show the longest average interval (33.98 days) while students going from San Diego to Port Hueneme show the shortest average interval (18.23 days).

KNOWLEDGE DECAY IN BE/E GRADUATES

Average knowledge decay as the difference between the BE/E retest and final test is shown in table 4. Using paired t-tests, retest scores were found to be significantly lower than test scores (overall test, $t = 16.01$, $p < .001$; phase 1 test, $t = 7.45$, $p < .001$; phase 2 test, $t = 19.6$, $p < .001$).

The proportion of knowledge decay, calculated as the difference between test and retest scores divided by the test score, was regressed on AFQT score and retention interval to determine the extent to which general intelligence and length of time between tests predict knowledge decay. The results of the regression analyses are shown in table 6.

For both phases of the test, AFQT and interval significantly predict the proportion of decay in knowledge that occurs. AFQT has a negative coefficient with decay when the interval between tests is held constant, while interval has a positive coefficient when AFQT is held constant. Thus, as AFQT increased, decay would decrease, and as interval increased, decay would increase.

RATE OF DECAY IN PHASE 1 AND PHASE 2. From table 4, it appears that more decay occurs in phase 2 (AC) than it does in phase 1 (DC). A paired t-test between the proportions of decay for phase 1 and phase 2 shows that there is a significantly greater proportion of decay in phase 2 knowledge (mean proportion = .24) than there is in phase 1 knowledge (mean proportion = .06, $t = 16.9$, $p < .001$).

TABLE 4. AVERAGE BE/E TEST AND RETEST SCORES AND DIFFERENCE SCORES

		FINAL BE/E TEST SCORE Raw Scores[2]			BE/E RETEST SCORE Raw Scores			RETEST-TEST DIFFERENCE Raw Scores		
BE/E School	CE "A" School	Overall	Phase 1	Phase 2	Overall	Phase 1	Phase 2	Overall	Phase 1	Phase 2
Great Lakes (N[1] = 82)	Port Hueneme (N = 32)	60.35	39.55	20.81	50.34	35.94	14.41	-10.01	-3.62	-6.4
	Gulfport (N = 50)	61.22	39.50	21.72	52.40	37.62	14.78	-8.82	-1.88	-6.94
San Diego (N = 65)	Port Hueneme (N = 53)	61.32	40.06	21.26	58.75	40.11	18.64	-2.59	0.05	-2.62
	Gulfport (N = 12)	61.36	39.64	21.71	55.50	38.29	17.21	-5.85	-1.35	-4.5
Orlando (N = 117)	Port Hueneme (N = 40)	61.61	40.05	21.56	49.34	35.54	13.80	-12.27	-4.51	-7.76
	Gulfport (N = 77)	62.23	40.01	22.22	52.26	37.24	15.02	-9.97	-2.77	-7.20

[1]N is the number of graduates.

[2]Maximum raw scores: overall - 76; phase 1 - 47; phase 2 - 29.
Overall raw scores may not equal the summation of phase 1 and phase 2 raw scores due to rounding.

TABLE 5. AVERAGE RETENTION INTERVAL IN DAYS

	CE "A" SCHOOL	
BE/E School	Gulfport	Port Hueneme
Orlando	28.96 (97)*	33.98 (40)
San Diego	25.43 (14)	18.23 (53)
Great Lakes	26.44 (50)	26.97 (32)
Average Interval	27.87	25.50

*Number of students.

TABLE 6. STANDARDIZED REGRESSION ANALYSES OF KNOWLEDGE DECAY ON AFQT AND RETENTION INTERVAL

	AFQT	Interval	R^2	F	Signif.
Phase 1	-.172	.259	.10	14.8	$p < .001$
Phase 2	-.144	.379	.17	27.1	$p < .001$

NOTE: All standardized coefficients are significant at the .01 level or less. Correlation between AFQT and Interval is -.027.

Given the difference in proportion of decay between phase 1 and phase 2, and the apparent difference between the regression coefficients of interval with phase 1 and phase 2 decay (table 6), there might be a difference in the rate of decay in phase 1 and phase 2 scores. If this difference in rates exists, then, in a given amount of time, and for a fixed level of intelligence, the decay in phase 2 scores would be proportionally larger than the decay in phase 1 scores. This difference in decay rates would be indicated by a significant difference between the regression coefficients of retention interval with decay for phase 1 and phase 2.

These two coefficients cannot be tested directly using a standard t-test since they are not independent. However, there is a test for dependent correlations (Cohen & Cohen, 1975). Since the multicolinearity between AFQT and Interval is so low (-.027), the beta coefficients should

act very similarly to correlation coefficients. This test shows that there is a significant difference between the correlation of Interval and phase 1 decay and the correlation of Interval and phase 2 decay ($t = 2.02$, $p < .05$). Also, there is no difference between the analogous AFQT correlations ($t = .354$). These findings indicate that the rate of decay for phase 2 knowledge (AC theory) is greater than the rate of decay for phase 1 knowledge (DC theory).

PREDICTING CE "A" SCHOOL PERFORMANCE

CE "A" School final grades were available for 88 graduates from Gulfport. A summary description of these grades is shown in table 7.

To determine whether CE "A" School performance could be predicted by AFQT or ASVAB composite, and decay in knowledge, CE "A" School final grades were regressed on AFQT score and proportional decay in BE/E test scores and on ASVAB score and decay. Separate regressions were run for decay in total test score, phase 1 test score and phase 2 test score. The results are shown in tables 8 and 9. AFQT and ASVAB show a significant positive relationship with CE "A" final grade while the proportion of decay shows no significant relationship with CE "A" final grades.

TABLE 7. GULFPORT CE "A" FINAL GRADES

	Range	Min	Max	Mean
Great Lakes (31)*	23.44	70.0	93.44	86.15
San Diego (4)	11.04	79.87	90.91	87.60
Orlando (53)	26.1	70.0	96.1	85.70

*Number of students.

TABLE 8. STANDARDIZED REGRESSION OF CE "A" SCHOOL GRADE ON AFQT AND DECAY IN BE/E TEST SCORES

Score Used for Decay	AFOT	Decay	R^2	F	Signif.
Total Score	.261*	-.06	.08	3.5	$p < .03$
Phase 1 Score	.261*	-.08	.08	3.6	$p < .03$
Phase 2 Score	.267*	-.03	.08	3.4	$p < .04$

*These beta coefficients are significant at the .02 level.

TABLE 9. STANDARDIZED REGRESSION OF CE "A" SCHOOL GRADE ON ASVAB COMPOSITE AND DECAY IN BE/E TEST SCORES

Score Used for Decay	ASVAB	Decay	R^2	F	Signif.
Total Score	.259*	-.04	.08	3.5	$p < .03$
Phase 1 Score	.256*	-.07	.08	3.6	$p < .03$
Phase 2 Score	.270*	-.01	.07	3.4	$p < .04$

*These beta coefficients are significant at the .02 level.

SELECTION CRITERIA ANALYSES

A separate statistical analysis was performed to determine how changes to the currently used ASVAB criteria for selecting students for CE training would affect academic attrition rates in BE/E School. The results of this analysis are trade-off curves showing the percentages of erroneous decisions for different ASVAB composite cut-off scores. These curves are shown and discussed in the next section.

SECTION IV

DISCUSSION

This section is devoted to discussions of the findings related to BE/E knowledge decay, factors related to the decay, and the final "A" School grades of graduates. In addition, the probable effects of altering ASVAB selection criteria are discussed.

KNOWLEDGE DECAY

The finding that the retest scores were lower than scores on the final BE/E test indicates that there is a decay in BE/E knowledge. The average student lost about 24 percent of AC theory knowledge and about 6 percent of DC theory knowledge.

Several explanations for these decay differences may be offered. Different types of knowledge (content) may have inherently different rates of decay. However, the observed differences in amount of decay could also be attributed to such factors as unequal learning of the two content areas, different test difficulties, or to situational aspects of the retest procedures at CE "A" School. The higher retest scores on phase 1 could have occurred because students learned the DC material better than they did the AC material. And, psychological learning theory asserts that higher degrees of learning lead to less forgetting (e.g., Hilgard and Bower, 1966). If unequal learning is a factor in AC knowledge being less well retained than DC knowledge, this in turn could be attributed to some combination of greater inherent difficulty of the AC area and instructional deficiencies.

It is also possible that the observed differences in phase 1 and phase 2 scores could be due to differences in the two test phases. The material covered in each phase could have been equally well learned, but a more difficult phase 2 (AC) test could have resulted in lower phase 2 scores both on the final test and on the retest. Finally, the study materials given the students prior to the retest could have favored DC knowledge to a greater extent than AC knowledge. Given more practice on DC items, student retest scores on that phase could have been raised relative to the AC part of the test.

FACTORS RELATED TO KNOWLEDGE DECAY

Several variables were investigated for their contributions to knowledge decay. These variables include:

- the ability characteristics of a student
- the retention interval (i.e., backlog time and/or transit time between the final test and retest)
- the locations of the BE/E Schools and CE "A" Schools.

ABILITY CHARACTERISTICS. Higher ability students were found to have less decay of BE/E information than lower ability students with the same retention interval. This finding suggests that knowledge decay could be lessened by raising ability level requirements to enter the training pipeline. This could be done by adjusting selection cut-off scores, and perhaps by changing the current ASVAB subtest selector composite. This topic is discussed below in greater detail under the heading, "Predicting Academic Attrition in BE/E School."

RETENTION INTERVAL. The number of days between the final BE/E test and the retest (i.e., retention interval) was the major factor influencing the amount of knowledge decay. This finding was substantiated when the influence of school location on the amount of knowledge decay was examined.

School Location. There were no significant differences in overall average retest scores between the CE "A" Schools; however, there were significant differences in the retest scores depending on which BE/E School was attended. Graduates who entered CE "A" School at Port Hueneme from San Diego had significantly higher average retest scores (i.e., less knowledge decay) than BE/E graduates from Orlando and Great Lakes. However, the retest scores were not significantly different at the CE "A" School in Gulfport regardless of the BE/E School attended.

One interpretation is that BE/E training at San Diego is superior to the training at the other BE/E Schools. However, this interpretation can be discounted since the results showed that the final BE/E test scores were equivalent at all three BE/E locations. In addition, the mean AFQT and ASVAB scores were similar across all three BE/E Schools. Thus, all three BE/E Schools are training the same kind of student in terms of ability, and the output student quality level is uniform. Therefore, the alternative explanation is the difference in retention interval. BE/E graduates from San Diego who attended CE "A" School at Port Hueneme had the shortest average retention interval (i.e., 18 days), while BE/E graduates from Orlando and Great Lakes had considerably longer average retention intervals, ranging from 25 to 34 days depending on CE "A" School attended.

Since retention interval is the most powerful predictor of knowledge decay, a decrease in transit time between BE/E and CE "A" Schools should reduce knowledge decay. However, a reduction of transit times involves scheduling problems that are created by unequal distances between the schools and by the irregularity of BE/E graduation dates relative to the starting dates of CE "A" Schools. The effect of unequal distances can best be seen by comparing the knowledge decay of the San Diego/Port Hueneme combination, with the shortest travel distance and retention interval, to the knowledge decay of other BE/E School-CE "A" School combinations. The other problem area (i.e., BE/E graduation and CE "A" starting dates) is a result of the different methods of instruction. BE/E students under computer-managed instruction (CMI) graduate individually, while CE "A" Schools, having group-paced (GP) instruction, commence classes periodically. Sending BE/E graduates to the CE "A" School that convenes next would tend to minimize the retention interval and, therefore, the knowledge decay.

FINAL GRADES

The final grades of Gulfport CE "A" graduates were used as measures of CE "A" School performance. Knowledge decay did not predict this performance. This finding, however, should not necessarily rule out the influence of knowledge decay on CE "A" performance. Whatever effects decay might have would likely show up in a student's early school performance. As time in CE "A" progresses, lost knowledge may be reacquired by the student through his own efforts or by the instructor's taking time away from CE training to remediate the student. Thus, end-of-course grades would be insensitive to the decay effects.

PREDICTING ACADEMIC ATTRITION IN BE/E SCHOOL

The rate of academic attrition in the current sample of BE/E students in the CE "A" School pipeline was 14 percent. During TAEG interactions with CNTECHTRA, some questions were raised concerning the appropriateness of both the current ASVAB composite makeup (i.e., subtests involved) and the current cut-off score used for selection for the CE "A" pipeline. Discriminant function analysis (Nunnally, 1978) was used to determine if there was a more efficient set of composites and/or cut-off scores that could be used to discriminate between BE/E graduates and academic attrites. The results of the discriminant function analysis are shown in appendix B.

Based on the discriminant function analysis, the three ASVAB subtests that discriminate best between BE/E graduates and academic attrites are mathematical knowledge (MK), electronics information (EI) and mechanical comprehension (MC). Based on the discriminant function coefficients, MK and MC were multiplied by a factor of two, so the best ASVAB composite based on the discriminant function analysis is EI + 2 (MK + MC). However, even though this new ASVAB composite discriminates between graduates and academic attrites slightly better than the old composite, the improvement is so slight as to be of no practical consequence. Therefore, instead of merely considering the ability of composite scores to predict graduation, the trade-off curves of various cut-off scores for both composites were also considered.

SELECTION CRITERIA TRADE OFFS. In making a decision to admit a student into a training pipeline, there are two kinds of mistakes that can be made. A false positive mistake is admitting a student who later fails. A false negative mistake is not admitting a student who would have succeeded. In selecting a cut-off score there will almost always be a trade off between false positive and false negative decisons. A lower cut-off score will reduce the rate of false negative decisions, but it will increase the rate of false positive decisions. Conversely, a higher cut-off score will decrease the rate of false positive decisions but increase the rate of false negative decisions. Trade-off curves help to show the effects of changing cut-off scores on the rates of false positive and false negative decisions. However, trade-off curves do not necessarily show which particular cut-off point is the best one. A cut-off point should be selected based on the relative costs of false negative and false positive decisions.

Both false positive and false negative mistakes have costs attached to them. The cost of making a false positive decision is the time and money spent training a student who will not pass the course. This cost can be fairly easy to determine since it will be a function of the actual costs incurred by the student while in training. The cost of making a false negative decision is that a student who would have successfully finished training is not selected. Thus, a potential trained person is lost. The cost of this mistake is harder to determine; it will largely be a function of the availability of qualified personnel.

Selecting a specific cut-off point for a composite ASVAB score (or any other entry criterion) should involve examination of a trade-off curve. Also, a decision must be made concerning a desirable mix of false positive and false negative decisions. In some cases, it will be desirable to reduce false positive decisions and in other cases it will be desirable to reduce false negative decisions.

Reduction of false negative decisions, with a concommitant increase in false positive decisions, is desirable when the availability of qualified manpower is low relative to the number of personnel required. In this case, the cost of training people who will not complete the pipeline is offset by the need for a given quantity of trained personnel. This decision would necessitate lowering the ASVAB composite score required for entry into a training pipeline.

Reduction of false positive decisions is desirable when the pool of available qualified manpower is large and the cost of training is high. Increasing the required composite entry score would increase false negative decisons and decrease false positive decisions. Thus, few students would enter the pipeline and subsequently fail, while more students who could have passed would be denied entry. This would result in lower training costs per students but is practical only if the qualified applicant pool is large.

For the specific case of the CE "A" School pipeline, trade-off curves using both the current ASVAB composite and the new composite based on discriminant function analysis are shown in figures 1 and 2.

With the ASVAB subtest composite and cut-off score currently used (i.e., 200), the total percent of wrong decisions is approximately 23 percent. False positive decisions amount to about 10 percent and false negative decisions amount to about 13 percent. When the cut-off score is lowered to 190, as is the actual case when waived students are considered, the false positive rate increases to about 14 percent while the false negative rate falls to about 8 percent. Conversely, if the cut-off score were raised to 210, the rate of false positive decisions would fall to about 7 percent while the rate of false negative decisions would increase to 33 percent.

The trade-off curve for the alternative composite shows essentially the same relationships between cut-off score and percent of false decisions but the rate of change in error rates is somewhat different. Specifically, raising the cut-off score does not result in as rapid an increase in false negative decisions for the alternative composite as it does for the current composite.

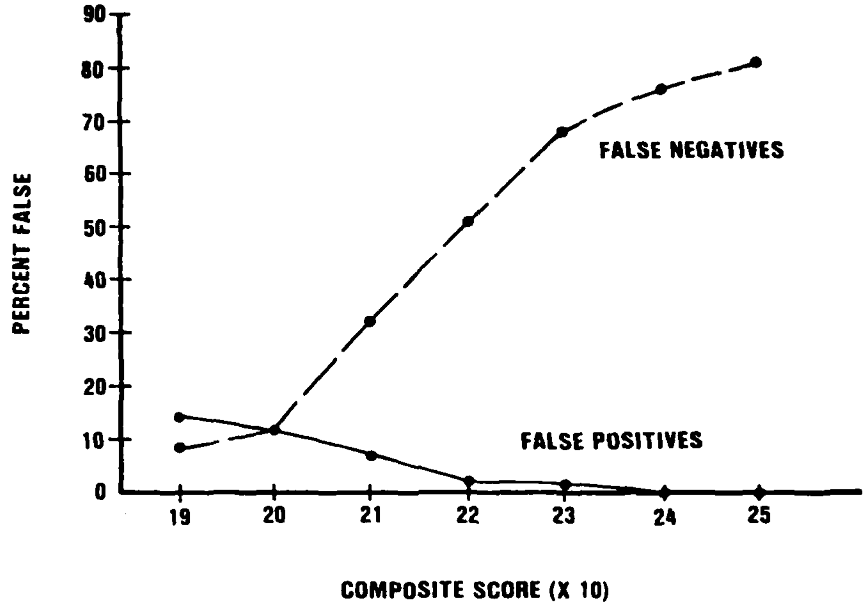

Figure 1. Trade-Off Curves for the Current ASVAB Composite

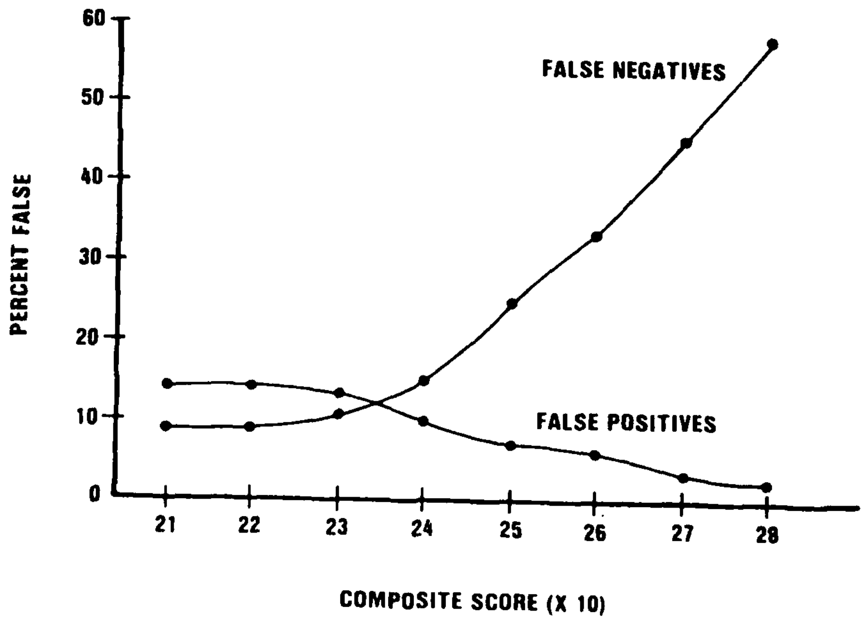

Figure 2. Trade-Off Curves for the Alternative ASVAB Composite

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. There is a decay in BE/E knowledge over time. Decay is greater for phase 2 knowledge (AC theory) than for phase 1 knowledge (DC theory). The average student lost about 24 percent of tested AC theory knowledge and about 6 percent of tested DC theory knowledge.

2. The amount of knowledge decay increases as the time between tests increases.

3. The amount of knowledge decay increases as student ability decreases. Over the retention intervals examined, higher ability students lost less knowledge than lower ability students.

4. There were no differences in ability or BE/E test scores among the three BE/E Schools. Also, students at both CE "A" Schools had about the same overall average retest scores. However, students who attended BE/E School in San Diego and CE "A" School at Port Hueneme had higher retest scores and less knowledge decay. This was attributed to the much smaller time interval between tests for this group of students than for other groups.

5. Students with higher ability tend to get higher final grades. Knowledge decay did not influence CE "A" final grade. However, final grades may not be sensitive to detecting decay effects.

6. The current ASVAB composite is as good as any available composite for predicting success in BE/E School. Selecting a particular cut-off score is important. Trade-off curves are a useful means for doing this.

RECOMMENDATIONS

1. Determine the relative costs of false negative and false positive decisions for entry into the CE "A" pipeline. If there are large numbers of qualified students for entry into the pipeline, then consider raising the entry criteria. If there are fewer qualified students than openings, then consider lowering the criteria.

2. Reduce the mean time delay between BE/E graduation and CE "A" School entry. This could be achieved by sending BE/E graduates to the CE "A" School with the earliest convening date.

3. Even the most efficient pipeline will have delays between schools. Also, since the individualized BE/E School graduates students constantly and the CE "A" Schools class up periodically, some delay waiting for instruction is inevitable; therefore, BE/E students should be routinely tested for their retention of BE/E knowledge and given remediation if indicated.

4. The results of this study suggest that AC theory may be less well learned by BE/E students than DC theory. Further investigations are recommended to determine if the quality of AC instruction is equivalent to the quality of DC instruction.

5. Continue, over the long term, investigations of knowledge loss and its relationship to subsequent learning and performance. A recommended initial effort in this area is to extend the present type of study to investigate knowledge loss for a large sample (2,000-3,000) of BE/E graduates going into other ratings. This investigation could confirm the results of the present study and permit better development of retention curves over longer periods of time. Part of this effort should also be devoted to determining absolute knowledge losses under conditions where students are not first provided opportunity to review BE/E material before being retested.

6. Investigate knowledge losses for conventionally taught courses to determine if results similar to those for this CMI course are obtained.

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Cohen, J. and Cohen, P. Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. Hillsdale, NJ: Lawrence Erlbaum Associates, 1975.

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APPENDIX A

INSTRUCTIONS FOR TESTING BASIC ELECTRICAL KNOWLEDGE

This appendix presents the instructions developed by CNTECHTRA for testing BE/E knowledge at the CE "A" Schools.

INSTRUCTIONS FOR TESTING BASIC ELECTRICAL KNOWLEDGE

Background

Serious questions have been raised about the effectiveness and relevancy of the BE/E preparatory training given to prospective CE "A" School students. This is a multifaceted problem requiring careful analysis if specific problem aspects are to be isolated, quantified, and remedied.

Purpose

As part of the larger analysis of the BE/E program, the thrust of this particular study (i.e., BE/E re-testing) will be to measure knowledge retention among BE/E graduates, evaluated against each of several variables which may affect knowledge retention. Since careful data collection in this regard can be significant in identifying methodology deficiencies in the present instructional system, it is vital that the testing and information processing procedures outlined herein be consistently applied....

Procedure

1. When a student checks aboard NAVCONSTRACEN, a designated school official will extract the following information from that student's service record: name, social security number, BE/E school location, BE/E graduation date, and composite ASVAB Score (AR + 2 MK + GS). This information will be retained by this designated school official until receipt of the completed examination answer sheets from the CE "A" School instructor. (See Item 4 below.)

2. At the beginning of the sixth period of the second day following class-up, the instructor will make the following announcement to his CE "A" School students: "Tomorrow morning first period you will be given a multiple choice examination to test your knowledge of basic electricity. This test will cover essentially the same subject areas that you studied in BE/E School. This test is being given to ensure that you have an adequate knowledge of the principles of electricity to successfully complete Construction Electrician "A" School. A good knowledge of electricity is important to your success in the Navy because you will be using this knowledge every day, both as a student and as a CE."

"While there will not be a 'Passing' or 'Failing' test score as such, the test results <u>will</u> be used to identify any of you who may need assistance in any of the basic electricity subject areas. You will have use of a Study Guide for the next two hours in this classroom to refresh yourself on the material you covered in BE/E. You will not be allowed to take this Study Guide away from the classroom this afternoon after class, so make good use of the time you have available. I will be available for the next two hours to answer any specific individual questions you may have, but I do not intend to conduct group lectures on any of the BE/E subject areas." Pass out Study Guides at this time.

Notes:

a. This should be the first time that the students learn they will be tested on BE/E material.

b. Students are not to be told that they will be taking the same identical examination that they took in BE/E.

c. If demand warrants, two instructors should be available in the classroom during this two hour review period.

d. Ensure that none of the students to be tested the following day is scheduled for some extraordinary activity (such as a mid-watch) on the evening of the second day, as this would bias the test results.

3. On the morning of the third day (first period), the re-examination will be given. Have the students complete answer sheet heading items 1, 2, 3, 5, 6, 8, 9, and 10 as described in Attachment (A) herewith (two answer sheets each) prior to passing out examination booklets. Tell the students "You will be allowed 1-1/2 hours to complete the test. If you don't know the answer to a particular test question, it's to your advantage to guess at it. You may now start the test." (Note to the Test Proctor: If a student does not comprehend a word or phrase within a test question, you may clarify the meaning of that word or phrase. You must be careful, however, to avoid "leading" the student to the selection of any particular answer choice.)

4. After completing the examination and properly accounting for and securing all test booklets, the answer sheets are to be turned-in as designated by the school CISO. The designated school official will then enter data elements 4 and 7 on each answer sheet, as described in Attachment (A), and will verify the accuracy of data elements 1, 5, 6, 9, and 10. The complete package of answer sheets for each CE "A" School class is to be mailed to CNTECHTRA Code N422 within five working days of the examination date. (Note: Prior to mailing the answer sheets to CNTECHTRA, they may be manually graded for local school use; however, care must be taken to avoid extraneous marks on these answer sheets, as they will be processed by ADP equipment at CNTECHTRA.)

ANSWER SHEET HEADING

	Data Element	Entry Instructions
1.	Learning Center	Enter "GP" or "PH," depending on CE "A" School location
2.	Name	Self-explanatory
3.	Rate/Rank	Self-explanatory
4.	Test (See Instructions below)	Enter student's ASVAB score as determined from Service Record (CE ASVAB = AR + 2 MK + GS)
5.	School	Enter "San Diego," Great Lakes," or "Orlando" depending on where student attended BE/E training
6.	Date	Date of this particular test; e.g., "6 APR 81"
7.	Carrell (See Instructions below)	Enter the date the student graduated from BE/E
8.	Social Security #	Self-explanatory
9.	Course #	Enter "71"
10.	Test #	Enter "021202" on first answer sheet (Exam Part I); enter "021203" on second answer sheet (Exam Part II)

Instructions

With the exception of data elements 4 and 7, the student should complete all required test heading data prior to commencing the examination....

ATTACHMENT (A)

APPENDIX B

DISCRIMINANT FUNCTION ANALYSIS WITH ASVAB SUBTESTS AND GRADUATION OR ACADEMIC ATTRITION FROM BE/E

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